Full Proposal Narrative

(Revised to describe work to be completed in Phase 1 and Phase 2)

QUANTIFYING POTENTIAL FOR OYSTER AQUACULTURE AND IMPACTS ON ESTUARINE NITROGEN RELATED WATER QUALITY: COCKEST POND AND THE EAST BRANCH OF THE WESTPORT RIVER

Grant Proposal Submitted to:

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I, NEW ENGLAND
SOUTHEAST NEW ENGLAND PROGRAM FOR COASTAL WATERSHED RESTORATION

By:

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(FULL PROPOSAL)

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i. **Project Title:** Quantifying Potential for Oyster Aquaculture and Impacts on Estuarine Nitrogen Related Water Quality - Cockeast Pond and the East Branch of the Westport River

ii. **Applicant Organization:** University of Massachusetts-Dartmouth, School for Marine Science and Technology (Coastal Systems Program)

iii. **Project Partners:** Westport River Watershed Alliance (WRWA), Town of Westport Shellfish Department, Aquaculture Research Corporation (ARC)

iv. **Key Personnel Contact Information:** Dr. Brian Howes (bhowes@umassd.edu, 508-326-0912), Dr. Roland Samimy (rsamimy@umassd.edu, 508-951-6795), Dr. David Schlezinger (dschlezinger@umassd.edu, 508-910-6314)

v. **Project Cost:** Total Project Cost ($973,189) Federal Funds ($884,717), non-federal match/cost share ($88,472); Budget is divided into phases, with Phase I of $525,967 (Federal) and $52,597 (match), Phase II of $358,750 (Federal) and $35,875 (match).

Programmatic Capability and Past Performance: The proposed work will be led by the Coastal Systems Program (CSP) at the School for Marine Science and Technology (SMAST), University of Massachusetts Dartmouth (UMassD). The Coastal Systems Program was established to provide research quality information to address the growing ecological degradation of coastal (estuarine) and freshwater (lacustrine, wetlands) ecosystems. The goal of the CSP is to fill the niche between basic and applied research to provide high quality scientific support for management of coastal and inland aquatic ecosystems (bays, harbors, wetlands and watersheds). The nutrient biogeochemistry laboratory of CSP has conducted research on coastal ecosystems for ca. 30 years, providing analytical capabilities required for quantitative ecological research in the coastal zone. CSP's analytical facility supports estuarine research funded by NSF, EPA, WBNERR, NOAA-Sea Grant, NOAA-Estuarine Programs, MassDEP, Mass Bays Program, South Florida Water Management District (SFWMD), and various states, cities and towns. Nutrients are measured using a variety of instruments and state-of-the-art methods developed over 30 years of estuarine research. Due to the large number of samples processed (~35,000 samples annually), many instruments are interfaced with computers to allow greater accuracy and ease of data transfer. Specialized instrumentation, such as auto-analyzers, fluorometers, gas chromatographs and spectrophotometers are utilized to provide highly sensitive measurements of various nutrients and gases frequently found at very low concentrations in the natural environment. All analytical methods have the required sensitivity for detection of low concentration analytes in natural waters (salt and fresh). Communities representing over half of the coastal embayments in Massachusetts currently use data generated by the CSP laboratory for management and policy decisions regarding restoration and remediation of their aquatic systems. Moreover, for the past 14 years, scientists from the CSP have been engaged in the completion of New England's largest estuarine restoration program, the Massachusetts Estuaries Project (MEP, budget: $12.5 million split between state and municipal funds), which is guiding nitrogen management and estuarine restoration for the entire southeastern Massachusetts region. The MEP Technical Team, led by CSP scientists, has produced over 65 estuary-specific technical reports that quantitatively establish the estuary specific nitrogen thresholds for restoration. These technical reports are the official basis for the development of nitrogen TMDLs by the MassDEP. To date, scientist from the CSP have assisted the Massachusetts Department of Environmental Protection in the submittal of over 15 TMDL documents to the US Environmental Protection Agency. The program is the basis for

infrastructure improvement and other restoration activities across southeastern Massachusetts with associated costs that are projected to total $4-$6 billion over the next 20-30 years. In addition, the CSP led MEP Technical Team is regularly assisting communities such as the Town of Westport (location of Cockeast Pond) in evaluating innovative nitrogen management options to attain the nutrient thresholds for estuaries in the MEP study area. Primary technical leaders from the MEP, who are also CSP scientists, will be leading the oyster experimentation effort in Cockeast Pond, namely:

1) Dr. Brian Howes - Director of the CSP and Technical Director of the MEP. Dr. Howes is a coastal ecologist and Professor with the School for Marine Science and Technology (SMAST) of the University of Massachusetts Dartmouth. His research centers on understanding the relationships between nutrient loading and the ecological health of coastal environments and their components: salt marshes, eelgrass, benthos. He focuses on the differentiation between natural processes and human impacts in these systems.

2) Dr. Roland Samimy - CSP Senior Research Manager. Dr. Samimy currently serves as the Technical Coordinator and Technical Lead in Hydrology for the Massachusetts Estuaries Project. Dr. Samimy's research centers on understanding the role surface water systems within a coastal watershed play in the attenuation of nitrogen during transport from watershed sources to estuarine receiving waters and how that attenuation can vary with respects to watershed characteristics. Dr. Samimy also serves as lead diver for all CSP diving tasks including those undertaken for the Cockeast Pond project.

3) Dr. David Schlezinger - CSP Senior Research Manager. Dr. Schlezinger is the MEP Technical Lead in Sediment Biogeochemistry and autonomous monitoring. Dr. Schlezinger directs the CSP estuarine and lacustrine instrumentation efforts, manages the analysis of dissolved oxygen and chlorophyll dynamics, water clarity analysis and bio-deposition measurement for all projects undertaken by the laboratory. It should be noted that Dr. Schlezinger's nutrient flux program employs an innovative quantification approach making the CSP a leader in the field (nationally and internationally). Over 2,000 sediment core samples have been collected and incubated over the past 15 years from a wide variety of estuarine systems in differing geographic regions. Dr. Schlezinger's technical program provides estuary specific input parameters to numerical water quality models being developed for managing water and habitat quality.

Each CSP senior scientist listed above has been a co-PI or critical team member on strategically related projects upon which the work being proposed for Cockeast Pond is based, specifically: a) Dry Season/Wet Season Nutrient Flux Characterization for the St. Lucie and Calooshatchee River Estuaries (SFWMD 2008/2014, $494,212), b) Little Pond Oyster Aquaculture Demonstration/Monitoring Project (Town of Falmouth, MA. 2012-2016, $152,853), c) Quantifying Impacts of Oyster Aquaculture on Estuarine Nitrogen Related Water Quality (Massachusetts Environmental Trust, 2015-present, $25,481) and d) Biogeochemical Transformations of Nutrients in Groundwater at the Sediment-Water Column Interface in Ashumet Pond, MA. (Air Force Center for Environmental Excellence, 2000-present, $699,549)

Partnerships: As a primary project partner, the Westport River Watershed Alliance (WRWA) is a nonprofit environmental and advocacy group formed in 1976 to protect and improve the natural resources of the Westport River watershed. WRWA's mission is to protect the environmental integrity of the Westport River watershed and its coastal environs in Buzzards Bay and to

advocate for the wise use and preservation of natural resources for the aesthetic, recreational and economic benefit of area citizens. WRWA educates the general public about the inter-relationship of our waters, soils, plants, animals, and people. WRWA has a long-standing working relation with CSP. Specifically, WRWA was a critical working partner with the CSP in the successful completion of the Massachusetts Estuaries Project nutrient threshold analysis of the Westport River Estuary that exchanges tidal waters with Cockeast Pond. Moreover, the vast majority of the baseline assessment work completed to date on the Westport River Estuary and Cockeast Pond has been in collaboration with WRWA scientific and advocacy staff. CSP and WRWA staff have also worked together successfully on detailed evaluations of nutrient loading from critical subwatersheds discharging to the Westport River in order to target highest loading areas for cost effective implementation of nutrient management strategies. The strength of the working relation between the WRWA and CSP will be leveraged for successful completion of this innovative application of oyster propagation to drive restoration of Cockeast Pond, an impaired tributary estuary to the broader Westport River system. Implementation of oyster aquaculture in Cockeast Pond and the East branch of the Westport River for water quality improvement exists within the larger management framework for the Westport River estuary and is one step towards achieving the nitrogen specific TMDL for one of the largest estuarine systems in southeastern Massachusetts. To that end and for the purpose of this proposal, WRWA will play an active role in field aspects of the project but also will serve as the main liaison between CSP scientists and the Town of Westport Shellfish Department, Town Board of Selectmen, the Westport Shellfisherman's Association (a strong supporter of the MEP effort) and more importantly the citizens of Westport.

Problem Overview: Based on the findings of the Massachusetts Estuaries Project (MEP 2002 to present and conducted by CSP), it is clear that estuarine water and habitat quality in Southern Massachusetts estuaries is impaired from nitrogen enrichment. As a result, towns across southeastern Massachusetts are now seeking new approaches for lowering estuarine nitrogen levels as these systems are integral to their communities and they want to achieve the MEP set nitrogen thresholds for restoration of their estuarine resources. While traditional sewage treatment is part of the solution for most communities, it is not always applicable (like in Westport) and so non-traditional approaches to nitrogen management are being developed, but their efficacy needs to be quantified. An approach gaining momentum is the use of shellfish, particularly oysters to increase water clarity and remove nitrogen. CSP has been at the fore front investigating oyster deployments/reefs as a means to improve nitrogen related water quality, quantifying the removal of water column nitrogen and quantifying the enhancement of sediment denitrification ($NO_3^- \rightarrow N_2$) to gauge nitrogen removal efficiencies. Oysters are being considered due to their high filtration rates, rapid growth, and ability to thrive in nutrient rich, warm, shallow waters over a range of estuarine salinities, as well as providing local economic benefits.

In this context, many Massachusetts communities have begun oyster propagation. However, almost none have quantified the integrated nitrogen removal through filtration, deposition and sediment denitrification and through harvest, nor accurately assessed resulting water quality improvements. As a result, it is difficult to compare the cost/benefit of using shellfish compared to other nitrogen management approaches (Traditional WW treatment, PRBs, floating wetlands, enhanced natural attenuation) or to accurately incorporate shellfish culture into management or regulatory processes. This critical piece of information is slowing the implementation of this "soft solution". The proposed project focuses first on nitrogen management of a eutrophic salt pond, Cockeast Pond (tributary to Westport River), and second on quantifying the nitrogen

processing and removal by the oyster/sediment complex. The pond has been selected due to its high level of nitrogen enrichment, its physical structure, its suitability for oyster culture and appropriateness for measuring nitrogen removal rates. The results are aimed at restoring this specific salt pond, but also providing quantitative information to the numerous towns throughout southeastern Massachusetts that are seeking new nitrogen removal approaches and considering the use of shellfish for nitrogen remediation. An added benefit will be that CSP-SMAST will be able to leverage other efforts making Cockeast Pond a Natural Laboratory supporting parallel University undergraduate and graduate teaching and research. This has already been tested, with Cockeast Pond being selected for the Marine Science Graduate Case Studies course (MAR-620), which will continue to be performed as the project progresses. This not only enhances environmental education, but also trains young scientists on the implementation and testing of new nitrogen removal approaches for years to come. The Natural Laboratory will also be used for public education and training, filling a critical need for Massachusetts and bringing additional resources to the effort.

Project Background: Based on the findings of the MEP nutrient threshold analysis of the Westport River estuary, the Town of Westport, MA. is currently engaged in pursuing a myriad of nitrogen management options in order to reduce the amount of the principal eutrophying nutrient (nitrogen) going into the River's waters. Reducing and managing the amount of nitrogen contributed to the Westport River from the overall watershed, as well as specific subwatersheds such as that to Cockeast Pond, will not only restore/protect these valuable ecosystems, but will also be a means of helping the Town achieve its nitrogen loading threshold for the West Branch of the Westport River Estuary. Reducing nitrogen outflow from Cockeast Pond is another mechanism to lower nitrogen concentrations in the West Branch and help keep nitrogen concentrations in the adjacent impaired West Branch at levels supportive of healthy habitat (e.g. eelgrass, animal communities). Equally important, Cockeast Pond itself is impaired by nitrogen enrichment with periodic phytoplankton blooms, oxygen depletion, low water clarity and is now beginning to experience some patchy macroalgal accumulations. Oyster deployments in Cockeast Pond will be used to lower nitrogen levels in Pond waters, which will also reduce nitrogen outflow from Cockeast Pond to the main estuary. Cockeast Pond is also potentially an incubator to support restoration of historic oyster reef areas in the East Branch of the Westport River estuary. Equally important, Cockeast Pond is ideal for assessing the amount of nitrogen removal by oyster harvest and enhanced sediment denitrification as it is enclosed, has a single outlet, is relatively shallow like most other estuarine basins in s.e. Massachusetts and has a scale where oyster propagation (0.5 – 1.0 million) should have a large effect on water quality, as opposed to more open larger systems where the "oyster effect" is diluted. CSP has been working with WRWA toward assessment and restoration of Cockeast Pond for several years to get to the present point where a valid restoration plan can be implemented. To date, the team has been collecting baseline water quality data (2008-2015) to quantify impairment from nutrient enrichment as well as to gain a preliminary understanding of the basin's suitability and sustainability for oyster deployments. This latter effort was conducted to determine if a detailed analysis for implementation and micro-siting is appropriate. Additionally, the CSP-WRWA collaboration has quantified tidal exchange between Cockeast Pond and the Westport River while also successfully completing preliminary dissolved oxygen, chlorophyll-a and benthic animal surveys in the pond to further understand the level of habitat impairment. In addition, as UMassD is currently developing Cockeast Pond as a Natural Laboratory, a water quality model has been developed which will include the effect of oysters on nitrogen cycling and the nitrogen

balance as data become available. Based on very limited oyster nitrogen removals, preliminary work indicates that 0.5 – 1.0 million oysters should provide a measurable improvement in Pond water quality, thus lowering the N discharge to the West Branch. Based on the MEP Linked Watershed-Embayment Nitrogen Threshold Analysis, within the West Branch of the Westport River estuary, to prevent further loss of eelgrass and to restore eelgrass to 1951 and 1995 levels, tidally averaged TN at long-term water quality station W-12 (East Branch) needs to be lowered to 0.48 mg L^{-1}. Additionally, the MEP determined the tidally averaged TN at long-term water quality station E-33 (West Branch) needs to be lowered to 0.49 mg L^{-1}. Oyster propagation can potentially assist in achieving these thresholds but the efficacy must be quantified and documented.

Project Objectives: The Water Quality Restoration by Oysters in Cockeast Pond aims for major nitrogen remediation and habitat restoration of this salt pond and information to assist other communities in s.e. Massachusetts seeking to use shellfish as a restoration tool. The project will determine: 1) the degree to which oysters can be effective in removing in situ nitrogen (burial, denitrification) and improve water quality in Cockeast Pond as well as the Westport River by reducing nitrogen in Pond outflow, 2) if Cockeast Pond can be used as an incubator for oysters for relay to the East Branch of the Westport River to re-establish oyster reefs in that portion of the estuary and help the Town of Westport achieve its MEP threshold at station E-33, 3) the level to which oysters grown in Cockeast Pond grow (survival and growth rates) in the East Branch and provide data for scaling oyster deployments for a measurable effect on water quality in the East Branch and 4) establish Cockeast Pond as a sustainable Natural Laboratory and a focus of University based undergraduate and graduate resources on nitrogen management, leveraging project resources while training young scientists and managers in the area of nitrogen management and estuarine restoration. CSP scientists in collaboration with WRWA technical staff propose to deploy oysters in a variety of circumstances (bottom, racks, bags) in Cockeast Pond to determine the best method for this basin and will use bags for grow-out of oyster seed for the other deployment areas and as a guide to full deployment in the Pond as part of this proposal. Meeting objectives will be guided by a Project Advisory Committee.

Timely Expenditure of Grant Funds (Project Schedule): The overall project would be undertaken over 4 years with suitability assessment and micro-siting analysis taking place in year 1. Based on historic data and assessment data collected in year 1, a small test deployment of ~20,000 oyster seed will be deployed to confirm viability in Cockeast Pond in advance of much larger oyster deployments in follow-on years. In the first quarter of year 1, seed for the test deployment will be obtained from the seed supplier (contacts already initiated on UMD funds) along with necessary gear (floating bags, rack, floats, moorings). Deployment approach and gear selection will be refined in year 1 in parallel with assessment work. Based on the siting and assessment data and data on the distribution of oyster viability across the salt pond, the larger seed order (~500,000 at 6mm) will be placed (fall 2016) for Cockeast Pond deployment in year 2 (summer 2017) of the project and a similar amount in year 3. The year 1 assessment work will be followed by the larger oyster deployment and up-scaling in years 2 and 3 with grow-out and monitoring of oysters in follow on years 2,3 and 4. Mature oysters (3”-3.5”) grown in Cockeast Pond will gradually be transferred to areas in the East Branch of the Westport River that are being considered for future oyster reef restoration. The East Branch of the Westport River will also serve as a backup location should Cockeast Pond prove inadequate for conducting large scale oyster deployments. All monitoring proposed for Cockeast Pond in summers of year 2, 3 and 4 (sediment flux, bio-deposition, denitrification) can and will also be undertaken at a smaller

scale in association with oysters transferred to the East Branch. Reporting of results will be an ongoing effort through the life of the project, however, final results and overall project data synthesis will be accomplished through the generation of a full project report in year 4. A graduate course at UMassD is already focused on Cockeast Pond and seed funds from UMassD have been allocated to support graduate student efforts, should SNEP support this effort. The current course in estuarine dynamics that is using Cockeast Pond as a case study will form the basis for continuing educational efforts and graduate research in years 2, 3 and 4 of the project as well as continued field efforts under the umbrella of the Natural Laboratory. There are currently 4 graduate students working within the Natural Laboratory and a full time Ph.D. student conducting thesis research. Expenditure of funds will be tracked quarterly with anticipated burn down of grant funds generally following an S-curve model. Funds will be reconciled against quarterly work completed with majority of funds to be expended on field work in year 2 and 3.

Project Description and Environmental Results:

Task 1- Oyster Deployment in Cockeast Pond. CSP has been involved with various oyster deployments across southeastern Massachusetts, as well as the use of various mechanisms for grow-out of seed. The Cockeast Pond project, as well as other oyster aquaculture projects on Cape Cod that have involved the CSP, will use certified oyster seed from the Aquaculture Research Corporation ARC located in the Town of Dennis, Cape Cod, MA. Only certified seed will be used for the project to insure high quality, disease free organisms for the highest chance of survivability. CSP scientists have already contacted ARC and determined based on past project experience that initial oyster seed sized no smaller than 6mm would be preferable at the outset of the project. An initial year 1 viability test deployment will involve approximately 20,000 seed followed by a 500,000 oyster seed deployment in years 2 and 3 in order to have a measurable "oyster effect" assuming a conservative 30%-50% mortality. Initial grow-out of the oysters will be in floating 4mm bags to grow the seed to ~1" and then some will be transferred to bottom plots, bottom racks or mid-water bags. A local supplier of aquaculture gear (Atlantic Aquaculture Supply, LLC., Warren, Rhode Island) has already been identified and contacted for the required gear for deployment of the oysters. The initial small scale deployment will be undertaken to determine the spatial distribution of growth and survivability as well as sediment suitability. Citizen and shellfish warden input during the first year of the project will be solicited to assist in the selection of specific locations for deployment (micro-siting). Support from landowners abutting the pond is being provided and the need for pond remediation has already been presented by CSP and WRWA in late summer 2015. In later years (based on the year 1 results) the "best" deployment approach will be used with the bias toward non-surface mechanisms. Ultimately, the push will be toward bottom deployment even if it is in the shallower areas of the pond. The concept is to establish a "permanent" oyster resource within Cockeast Pond for remediation and to serve as a source for relays to the East Branch of the Westport River. As oysters cultivated in Cockeast Pond reach maturity, they will be transferred to an area of the East Branch that has previously supported oysters as a mechanism for re-establishing that natural population. Oysters from Cockeast Pond will most likely be deposited on the bottom as they have existed previously. Water quality monitoring similar to that underway in Cockeast Pond will be undertaken to determine if the oysters in the East Branch are influencing nutrient related water quality in that portion of the estuarine system. Similar protocols will be followed to maximize cross-comparability of data. CSP staff and interns as well as staff from WRWA will assist in the maintenance of the grow-outs and monitoring of the growth rate. This effort will also receive input from the Town of Westport Shellfish Constable

who has a wealth of local knowledge and has agreed to provide logistical support as needed. It should also be noted that the CSP has maintained a summer internship program for almost 20 years with undergraduates from colleges nation-wide.

Phase 1: a) engage with Town of Westport Shellfish Warden to determine Town restrictions / criteria for micro-scale oyster test deployment;

b) engage with the Massachusetts Division of Marine Fisheries (DMF) to obtain appropriate permits to conduct shellfish research in Cockeast Pond;

c) acquire and assemble required gear for summer 2016 oyster test deployment;

d) obtain oyster seed from Aquaculture Research Corporation (ARC) August 1, 2016;

e) deploy small scale oyster viability test in Cockeast Pond, ~20-30,000 6 mm seed oysters deployed August 2016 and monitor in Cockeast Pond until November 2016, sink or move for winter;

f) determine the spatial distribution of growth and survivability as well as sediment suitability;

g) determine viability / mortality of test deployment and assess appropriateness of Cockeast Pond for full scale deployment under Phase 2 (year 2);

h) order seed (November 2016) for full scale deployment in summer 2017 under Phase 2 (year 2);

i) order and assemble gear for full scale deployment summer 2017.

Phase 2: a) initiate full scale oyster deployment (~500k) June 2017 and 2018;

b) evaluate efficacy of deployment approach (surface bags, mid-water bags, bottom racks);

Task 2 - Sampling for Cockest Pond Oyster Deployment (Water Quality). A sampling program will be implemented to quantify nitrogen removal by the oyster culture pilot deployment in Cockeast Pond. WRWA will perform all water quality sampling in coordination with CSP scientists charged with completing all chemical analyses and data synthesis. The sampling and chemical analyses will include the full suite of nutrient related water quality parameters as in previous water quality monitoring in Cockeast Pond and the Westport River to be directly cross comparable to long term records. Sampling locations will build upon pre-existing monitoring stations. Additional stations may be added as appropriate. Data collected under the proposed project will be compared to pre-oyster deployment analysis of water quality for comparison to the multi-year post-oyster deployment conditions. Post-deployment analysis will also be structured on an upstream / downstream difference approach (based on flow direction by ADCP) and a tidal exchange approach where the total nitrogen export from the pond is tracked with and without oysters. Key components will be changes in chlorophyll, POC/PON, ammonium, TSS, D.O. concentrations in water as it moves through the oyster deployment areas, as well as data from autonomous sensors (below). This latter approach is facilitated by the morphology and hydrodynamics of Cockeast Pond and the existence of tidal exchange studies in 2014 and 2015, which was part of its selection for this effort. Samples will be analyzed for:

temperature, salinity, total nitrogen (nitrate + nitrite, ammonia, dissolved organic nitrogen, particulate organic nitrogen), chlorophyll-a (Chl-a), pheophytin-a, orthophosphate, dissolved oxygen, transparency (secchi depth), and alkalinity. Weather, tide-status, and results of water quality monitoring will be documented, with sampling performed so as to minimize both tide (ebb tide sampling) and weather-related effects on samples. Salinity measurements will be correlated to rainfall and other relevant parameters. Quality assurance samples (field duplicates) will be collected (10% of total number of samples collected) with the goal of gaining acceptance of study results by MassDEP and USEPA.

Deliverable: Tables and graphs will be presented comparing pre- and post-oyster aquaculture water quality results for Cockeast Pond. Emphasis will be on changes in the net nitrogen export and water column nitrogen and pigment concentrations and shifts between various constituent pools.

Phase 1: a) monitor pond conditions (DO, Chla, temp, salinity, nutrients) before and during the small scale test deployment as part of setting a system baseline;

b) sample locations and collection will be tailored to establish clear baseline of in situ conditions prior to large scale deployment in year 2 (Phase 2) and capture any oyster effect as the oysters reach 2-3 inches.

Phase 2: a) continue the water column monitoring initiated under Phase 1 during the small scale test deployment;

b) monitoring stations will be added as necessary to accommodate the full scale deployment (upstream, downstream and within the deployment area);

c) monitoring will take place during the entire duration of the oyster deployment (June-November 2017) until the time the oysters are sunk to bottom of Cockeast Pond or relayed to the East Branch of the Westport River for the winter;

d) second full scale deployment of oysters in Cockeast Pond (summer 2018);

e) monitoring of the second full scale deployment during the summers 2018 and 2019 will be completed according to procedures used in summer 2017 and additional monitoring will be extended to oysters that were moved to the East Branch of the Westport River in the Fall 2017 or 2018;

Task 3 - Time-series Dissolved Oxygen (DO)/Chl-a Moorings (Intensive Sampling). CSP-SMAST scientists will conduct continuous monitoring via a mooring program of key water quality parameters to assess the impact of oyster aquaculture on the ambient water column in concert with the field water sampling effort. This task will follow protocols and procedures established under the time-series mooring (DO, Chl-a) program for the MEP analysis of the Westport River and for the Town of Falmouth's Oyster Pilot Project for cross comparability. Data collected will also be compared to time-series baseline DO/Chl-a data previously collected from Cockeast Pond during the summer of 2015 under pre-oyster conditions. A total of six YSI-6600 moorings will be deployed within, at the margins and distant from the oyster deployment area to record: DO, light attenuation (as an indicator of turbidity), Chl-a (via fluorescence), salinity, and water temperature. Moorings will be deployed in the mixed layer, with a surface and bottom (30cm from sediment) mooring within the footprint of the oyster deployment. The

moorings will be maintained from Jul. 1 – Sept. 30 when the oysters are most actively filtering pond water ("oyster effect" largest) and the pond water quality is lowest. Moorings will be calibrated bi-weekly. Calibration samples will be collected at the specific depth and location of each sonde. At the time of calibration, each sonde will be inspected, cleaned and the data will be downloaded. Sondes will then be returned to the moorings and secured. Calibration sampling will include triplicate Winkler samples for dissolved oxygen determination as well as collection of whole water for chlorophyll extraction, with light profiles being made for independent extinction determination.

Deliverable: Graphical representation of data, analysis relating temporal changes in parameters, frequency and duration above and below key benchmark levels, and correlations between inferred biological and physical processes producing observed changes. When presented with water column sampling data of nutrients we anticipate being able to determine transformations that have occurred as a result of oyster cultivation. Preliminary work indicates that water clarity increases and a lowering of chlorophyll a and POC/PON should be seen with this analysis.

Phase 1: a) limited deployment of dissolved oxygen and chlorophyll sensors to establish base line conditions in Cockeast Pond during small scale test deployment (~20-30,000 oysters, summer 2016);

Phase 2: a) full DO/Chla mooring deployment associated with full deployment of oysters (~500K) during the summers 2017 and the additional (~500K) during the summers 2018 (June - October) with follow-up in 2019;

b) data processing and synthesis November - December 2017

c) full DO/Chla mooring deployment associated with full deployment of oysters (~500K) during the summer 2018 (June - October);

d) data processing and synthesis November - December 2018 and 2019

Task 4 - Bio-deposition Rates and Bio-deposit Impact Areas. CSP scientists will quantify particulate capture and deposition from oysters within oyster aquaculture areas using particle traps attached to the oyster bags or separate cages over a range of particulate concentrations. A particle trap design was developed and successfully deployed in Green Pond, Falmouth, MA during summer 2015 to measure oyster bio-deposition (C,N) rates. While effective, it was determined based on 2015 results that modifications to the trap design maybe necessary to strengthen the signal of oyster bio-deposition in the treatment particle traps. As such and for the purposes of the Cockeast Pond proposal, a modified particle trap design maybe considered. The frame and funnel are secured below 0.5 m^2 floating oyster bags. Prior to deployment, traps will be filled with seawater that was previously collected from the system, filtered, and equilibrated to ambient temperature. The step of pre-filling of traps minimizes the background particulate concentration increasing the accuracy of the measurements. For each bio-deposition measurement event, the traps will deployed for approximately 24 hours with a minimum of three (3) but as many as five (5) events per July-September. Surface pond water samples will be collected during the particle trap deployment for comparative purposes. The surface pond water samples, as well as the trap samples, will be processed by the CSP analytical laboratory for chlorophyll-a, total suspended solids, and particulate organic carbon and nitrogen. TSS filters

will be analyzed for particulate organic carbon and nitrogen using a Perkin Elmer 2400 elemental analyzer. Data collected from particle traps will be used to track PON deposited by oysters and determine individual oyster bio-deposits and 24 hour bio-deposition rates. This will enable quantification of total PON removed to sediments from the water column via oyster bio-deposition and water column clearance rates of phytoplankton facilitated by large scale oyster culture. The overall area of sediment surface affected by oyster culture will be determined by tracking fecal pellet settling and dispersion using acoustic methods for measuring horizontal and vertical velocities. Two acoustic doppler current profilers will be deployed to determine average horizontal and vertical velocities of sinking particles on ebb tide and tidal spreading of bio-deposits. The ADCPs will be deployed in the oyster areas. Based upon these velocities and the average depth of the system, the approximate boundaries for fecal pellet deposition to the sediment will be calculated and the concomitant areal extent of impact beyond the culture area will be delineated. This acoustic method was developed by the CSP under funding from Nortek, with method testing in Green Pond, specifically for investigating bio-deposition in estuaries across the region.

Deliverables: Maps of tidally averaged fecal pellet deposition contours will be presented with overlays of oyster aquaculture boundaries. These maps will include deployment period references to water column particulate concentrations, TSS and Chl-a to further link in situ water column clearance rates and particle concentration dependent bio-deposition rates.

Phase 1: Limited activity on this task in 2016, as it requires the full scale oyster deployment that is scheduled for year 2, so measurements will be intensive in 2017.

Phase 2: a) In relation to full scale oyster deployment undertaken summer 2017 and 2018 (year 2/3), bio-deposition investigation will ascertain bio-deposit impact area;

b) acoustic doppler current profiling (ADCP) will be undertaken in association with summer 2017 and 2018 as the full scale deployment develops;

c) bio-deposition and impact assessment via ADCP and collection of particulate matter will be repeated in summer 2019 (year 4) full scale deployment

Task 5 - Sediment Core Incubations and Analysis of Denitrification and Oyster Bio-deposits. Intact sediment cores will be collected and incubated under in situ conditions during summer to determine the effect of oyster bio-deposits on sediment carbon and nitrogen re-mineralization rates, including denitrification. It will also provide sediment nitrogen regeneration rates to parameterize the water quality model for Cockeast Pond and how oysters effect overall water column nitrogen levels during the critical summer management period, when impairment is greatest. Changes in the sediment rates of regeneration and nitrogen removal via denitrification are primary factors for inclusion of oysters in nitrogen remediation plans. While harvest provides a partial measure of nitrogen removal by oysters, it appears that this is only a fraction (10%-50%) of the total nitrogen removal mediated by a oyster deployment. Accurate determination of the larger nitrogen removal and nitrogen regeneration response is being sought by multiple municipalities for investing in oyster deployments to lower estuarine nitrogen levels. Cockeast Pond provides the perfect system for accurately determining these responses and factors which control them, so that the results can be used for projections across a variety of estuarine conditions found in s.e. Massachusetts. The CSP will measure nitrogen regeneration as

in the MEP estuaries and denitrification using a state-of-the art N_2/Ar method also part of routine CSP analysis and tailored to investigating affects from oyster bio-deposition. The methods have been developed for these shallow estuaries where oyster deployments are in place.

Core Collection and Incubation: The concept in determining sediment nutrient regeneration rates and how these maybe altered by bio-deposition from oyster propagation will be to collect undisturbed sediment samples and incubate them under in situ conditions to allow natural exchange of nutrients between the sediment and overlying water under controlled conditions. The approach and methods which will be employed in this effort are currently being used by the CSP Technical Team for numerous estuarine studies in southeastern Massachusetts including the Massachusetts Estuaries Project. Rates of nitrogen release will be determined using undisturbed sediment cores incubated so as to obtain quantitative rates of oxygen uptake, nutrient flux and N_2 gas emission rate. Three time points will be collected at not less than 30 minute intervals. It is foreseen that incubations may last for up 8-12 hours. It is important to tailor the time of incubation to ensure an adequate "signal" for each of the flux constituents. 12-16 sediment cores annually (15 cm inside diameter) will be collected by SCUBA divers and cores will be transported to a shore side field lab. Water from Cockeast Pond will be collected and filtered for each batch of 4-8 core sites to replace the headspace water of the flux cores prior to incubation. The collected water will be filtered and used to replace the headspace water of the flux cores prior to incubation. All of the sediment incubations will be performed immediately upon return to shore side lab. Upon arrival at the shore-side field laboratory sediment cores are inspected for any surface disturbance or large fauna (for example crabs or fish) which cause rejection of these cores. The cores will be transferred to pre-equilibrated temperature baths, the headspace water overlying the sediment will be replaced with filtered water collected from the field collection site, the water overlying the sediment gently mixed with a magnetic stirrer and the headspace is sealed with a gas-tight closure fitted with sampling ports. The headspace will be set so as to maximize the signal and minimize the incubation time (ideally ~10 hours). Periodic 90 mL water samples will be withdrawn (volume replaced with filtered water), filtered into acid leached polyethylene bottles and held on ice for nutrient analysis. Ammonium and ortho-phosphate assays will be conducted within 48 hours and the remaining samples frozen (-20oC) for assay of nitrate + nitrite (Cd reduction: Lachat Autoanalysis), DON, silicate, dissolved organic phosphorus, total nitrogen, total phosphorus. Rates will be determined from linear regression of analyte concentrations through time. A “significant flux” is defined as one where the least squares regression of the headspace analyte concentration over time has a slope different from zero.

N_2 Analysis using High Precision Membrane Inlet Mass Spectrometry: N_2 excess will be measured using membrane-inlet mass spectrometry (MIMS). In the field, periodic 60 mL samples will be collected in glass serum bottles for denitrification assays. Bottles will be overflowed with three volumes of core water to ensure sample integrity. Samples will be held at air temperature and transported back to CSP-SMAST for analysis by mass spectrometry. All fluxes will be adjusted for water removals and measured activities within the headspace water. In the laboratory, sample water is pumped at ml/min rates through a gas permeable membrane in order to extract gas into the mass spectrometer inlet. Sample gas is analyzed by the mass spectrometer for masses 28 and 40 for determining the N_2 to Ar ratio. Calibration is made by comparison with a reference gas of known composition. A quadrupole mass spectrometer is used for its sensitivity and speed of analysis. Based on series of method related experiments, it was determined that the samples collected should be preserved before capping and once capped,

samples should be kept at room temperature to prevent bubble formation. Sample preservative will be either mercuric chloride or hydrochloric acid such that the pH is lowered to a value of 2.

Deliverables: Tabular and graphical summaries of benthic nutrient regeneration and denitrification rates will be presented with sediment carbon concentrations that drive those rates. Rate measurements will be presented in the context of water column particulate nitrogen levels, rates and areal extent of oyster bio-deposition to further delineate the impact area and role of oyster culture in modifying overall water quality.

Phase 1: a) limited sediment nutrient flux experiment to establish baseline conditions in advance of full oyster deployment;

Phase 2: a) full assessment of sediment biogeochemical cycling in relation to full oyster deployment (summer 2017), nutrient release/uptake + denitrification;

b) full assessment of sediment biogeochemical cycling in relation to full oyster deployment (summers 2018) and in the fully developed system in 2019, nutrient release/uptake + denitrification;

Transferability of Results and Collaboration Across SNEP Area:

Task 6 - Reporting and Community Engagement. Annual progress will be documented in the form of a Technical Memorandum summarizing work completed in a given year. Overall project results will be disseminated through a final report to EPA. The results will be presented in at an annual workshop at UMD's conference facility (ATMC) previously used for MEP municipal outreach efforts. The target audience will be municipalities in the SNEP region engaging in restoration of shellfish areas for nitrogen management. Outputs from the Natural Laboratory through its training of students and interns will be featured as well. Shellfish for nitrogen management is frequently a matter of public discussion at town boards and in the nitrogen management and CWMP arenas where CSP scientists often present findings of innovative approaches to N-management. Broad dissemination of findings across the SNEP region will also be facilitated as the CSP supports the majority of the water quality monitoring programs in southeastern Massachusetts and is in regular contact with these program managers. Moreover, CSP scientists involved in the MEP are now being asked by all the municipalities within the SNEP region to assist with implementation of innovative nutrient management solutions such as shellfish aquaculture among others. This demand for scientific support on the part of the municipalities in the SNEP region has been a major driver in the development of this proposal. Findings of this project will also be presented at local shellfish symposium typically held on Cape Cod due to the large shellfish industry in the region. Findings of the project will be submitted for presentation at the International Oyster Symposium/Conference (IOS), September 2017, United Kingdom. As additional public outreach, WRWA will disseminate project results on their website, while SMAST-CSP will narrate a publicly available blog on their website. Both will include pictures, narrated videos produced by SMAST media officer (A. Wartts), discussion of specific issues at Cockeast Pond and progress of the project.

Phase 1: a) Prepare semi-annual progress report to EPA and complete the annual progress report that documents findings from year 1 and plans for year 2;

b) Present findings from year 1 to the Town of Westport and update the Town and stakeholders of the plan for year 2 and the full scale deployment;

c) WRWA to initiate posting progress and results to the organization's web-site;

d) Project team to engage with UMD-SMAST Media Officer to develop a program for regular dissemination of project progress and results (video, picture gallery, blog);

e) Engage with the Dean of UMD-SMAST to establish Cockeast Pond as a Natural Laboratory for graduate case study in estuarine dynamics, nutrient management and restoration of coastal habitats.

Phase 2: a) Prepare semi-annual progress report to EPA and complete the annual progress report that documents findings from year 2 and plans for year 3 and produce the Final Report in year 4;

b) Submit initial project findings for presentation to the International Oyster Symposium/Conference (IOS), September 2017, United Kingdom (this may have to wait an additional year for results of full scale deployment to be undertaken in summer 2017);

c) Submit initial project findings for presentation to Massachusetts Shellfish Officers Association Annual meeting;

d) Continue with dissemination of project results through WRWA website and via the UMD-SMAST Media Office;

e) Attend in person workshop hosted by EPA Region 1 with other SNEP grant recipients to share project results and lessons learned (end of year 2).

f) Conduct a workshop for municipalities throughout southeastern Massachusetts to share project results and lessons learned and provide guidance relative to the use of shellfish for nitrogen mitigation.

Budget Detail (Phase 1)

BUDGET DETAIL: PHASE I University of Massachusetts-Dartmouth	Grant Funds	State Match	Other Match	Grant Total
EPA-R1-SNEP Budget Detail FY2016	**Section 320/104(b) request**	**Contribution**	**Contribution**	
Personnel				
B. Howes (Summer)	$ 23,521	$ -	$ -	$ 23,521
B. Howes (school yr+ Summer)	$ -	$ -	$ 24,625	$ 24,625
R. Samimy, (Sr. Scientitst)	$ 27,821	$ -	$ -	$ 27,821
D. Schlezinger (Sr. Scientist)	$ 25,671	$ -	$ -	$ 25,671
Sr. Research Scientist	$ 9,522	$ -	$ -	$ 9,522
Technical Associate (3)	$ 37,653	$ -	$ -	$ 37,653
GRA TBA-1 (2 yr)	$ 36,308	$ -	$ 16,072	$ 52,380
Interns (3/3mo summer, 2 yr)	$ 27,000	$ -	$ -	$ 27,000
TOTAL SALARY	$ 187,496	$ -	$ 40,697	$ 228,193
Fringe				
University fringe costs (30.83%)	$ 25,026	$ -	$ -	$ 25,026
TOTAL FRINGE	$ 25,026	$ -	$ -	$ 25,026
Total Salary and Fringe	$ 212,522	$ -	$ 40,697	$ 253,219
Operating Costs				
Travel (regional & local)	$ -	$ -	$ -	$ -
Supplies - analytical	$ 18,000	$ -	$ -	$ 18,000
Equipment - seed and gear	$ 57,500	$ -	$ -	$ 57,500
Contractual -WRWA	$ 60,000	$ -	$ 11,900	$ 71,900
Other (student fees)	$ 21,084	$ -	$ -	$ 21,084
TOTAL OPERATING COSTS	$ 156,584	$ -	$ 11,900	$ 168,484
Other				
Not Applicable				$ -
				$ -
				$ -
TOTAL OTHER	$ -	$ -	$ -	$ -
Total Direct Costs	$ 369,106	$ -	$ 52,597	$ 421,703
Indirect Costs				
B. Howes (Summer)	$ 13,150	$ -	$ -	$ 13,150
B. Howes (school yr+ Summer)	$ -	$ -	$ -	$ -
R. Samimy, (Sr. Scientitst)	$ -	$ -	$ -	$ -
D. Schlezinger (Sr. Scientist)	$ 18,472	$ -	$ -	$ 18,472
Sr. Research Scientist	$ 6,614	$ -	$ -	$ 6,614
Technical Associate (3)	$ 25,754	$ -	$ -	$ 25,754
GRA TBA-1 (2 yr)	$ 22,746	$ -	$ -	$ 22,746
Interns (3/3mo summer, 2 yr)	$ 14,850	$ -	$ -	$ 14,850
Supplies and Equipment	$ 41,525	$ -	$ -	$ 41,525
Contractual WRWA	$ 13,750	$ -	$ -	$ 13,750
TOTAL INDIRECT @ 55%	$ 156,861	$ -	$ -	$ 156,861
Total Budget	$ 525,967	$ -	$ 52,597	$ 578,564
Total Match				$ 52,597
TOTAL REQUEST	$ 525,967			

Budget Detail (Phase 2)

BUDGET DETAIL: PHASE II University of Massachusetts-Dartmouth	Grant Funds	State Match	Other Match	Grant Total
EPA-R1-SNEP Budget Detail FY2016	**Section 320/104(b) request**	**Contribution**	**Contribution**	
Personnel				
B. Howes (Summer)	$ 23,521	$ -	$ -	$ 23,521
B. Howes (school yr+ Summer)	$ -	$ -	$ 27,775	$ 27,775
R. Samimy, (Sr. Scientitst)	$ 19,200	$ -	$ -	$ 19,200
D. Schlezinger (Sr. Scientist)	$ 26,812	$ -	$ -	$ 26,812
Sr. Research Scientist	$ 10,390	$ -	$ -	$ 10,390
Technical Associate (3)	$ 24,575	$ -	$ -	$ 24,575
GRA TBA-1 (1 yr)	$ 18,154	$ -	$ -	$ 18,154
Interns (3/3mo summer, 2 yr)	$ 27,000	$ -	$ -	$ 27,000
TOTAL SALARY	$ 149,652	$ -	$ 27,775	$ 177,427
Fringe				
University fringe costs (30.83%)	$ 19,776	$ -	$ -	$ 19,776
TOTAL FRINGE	$ 19,776	$ -	$ -	$ 19,776
Total Salary and Fringe	$ 169,428	$ -	$ 27,775	$ 197,203
Operating Costs				
Travel (regional & local)	$ -	$ -	$ -	$ -
Supplies - analytical	$ 13,729	$ -	$ -	$ 13,729
Equipment - seed and gear	$ 22,500	$ -	$ -	$ 22,500
Contractual -WRWA	$ 40,000	$ -	$ 8,100	$ 48,100
Other (student fees)	$ 10,542	$ -	$ -	$ 10,542
TOTAL OPERATING COSTS	$ 86,771	$ -	$ 8,100	$ 94,871
Other				
Not Applicable				$ -
				$ -
				$ -
TOTAL OTHER	$ -	$ -	$ -	$ -
Total Direct Costs	$ 256,199	$ -	$ 35,875	$ 292,074
Indirect Costs				
B. Howes (Summer)	$ 13,150	$ -	$ -	$ 13,150
B. Howes (school yr+ Summer)	$ -	$ -	$ -	$ -
R. Samimy, (Sr. Scientitst)	$ -	$ -	$ -	$ -
D. Schlezinger (Sr. Scientist)	$ 19,293	$ -	$ -	$ 19,293
Sr. Research Scientist	$ 7,080	$ -	$ -	$ 7,080
Technical Associate (3)	$ 16,880	$ -	$ -	$ 16,880
GRA TBA-1 (1 yr)	$ 11,373	$ -	$ -	$ 11,373
Interns (3/3mo summer, 2 yr)	$ 14,850	$ -	$ -	$ 14,850
Supplies and Equipment	$ 19,926	$ -	$ -	$ 19,926
Contractual WRWA	$ -	$ -	$ -	$ -
TOTAL INDIRECT @ 55%	$ 102,551	$ -	$ -	$ 102,551
Total Budget	$ 358,750	$ -	$ 35,875	$ 394,625
Total Match				$ 35,875
TOTAL REQUEST	$ 358,750			

Budget Detail (Project Total)

Project Total Budget				
University of Massachusetts-Dartmouth	**Grant Funds**	**State Match**	**Other Match**	**Grant Total**
EPA-R1-SNEP Budget Detail FY2016	**Section 320/104(b) request**	**Contribution**	**Contribution**	
Personnel				
B. Howes (Summer)	$ 47,042	$ -	$ -	$ 47,042
B. Howes (school yr+ Summer)	$ -	$ -	$ 52,400	$ 52,400
R. Samimy, (Sr. Scientitst)	$ 47,022	$ -	$ -	$ 47,022
D. Schlezinger (Sr. Scientist)	$ 52,482	$ -	$ -	$ 52,482
Sr. Research Scientist	$ 19,912	$ -	$ -	$ 19,912
Technical Associate (3)	$ 62,228	$ -	$ -	$ 62,228
GRA TBA-1 (3 yr)	$ 54,462	$ -	$ 16,072	$ 70,534
Interns (3/3mo summer, 4 yr)	$ 54,000	$ -	$ -	$ 54,000
TOTAL SALARY	$ 337,148	$ -	$ 68,472	$ 405,620
Fringe				
University fringe costs (30.83%)	$ 44,802	$ -	$ -	$ 44,802
TOTAL FRINGE	$ 44,802	$ -	$ -	$ 44,802
Total Salary and Fringe	$ 381,950	$ -	$ 68,472	$ 450,422
Operating Costs				
Travel (regional & local)	$ -	$ -	$ -	$ -
Supplies - analytical	$ 31,729	$ -	$ -	$ 31,729
Equipment - seed and gear	$ 80,000	$ -	$ -	$ 80,000
Contractual -WRWA	$ 100,000	$ -	$ 20,000	$ 120,000
Other (student fees)	$ 31,626	$ -	$ -	$ 31,626
TOTAL OPERATING COSTS	$ 243,355	$ -	$ 20,000	$ 263,355
Other				
Not Applicable				$ -
				$ -
				$ -
TOTAL OTHER	$ -	$ -	$ -	$ -
Total Direct Costs	$ 625,305	$ -	$ 88,472	$ 713,777
Indirect Costs				
B. Howes (Summer)	$ 26,300	$ -	$ -	$ 26,300
B. Howes (school yr+ Summer)	$ -	$ -	$ -	$ -
R. Samimy, (Sr. Scientitst)	$ -	$ -	$ -	$ -
D. Schlezinger (Sr. Scientist)	$ 37,765	$ -	$ -	$ 37,765
Sr. Research Scientist	$ 13,694	$ -	$ -	$ 13,694
Technical Associate (3)	$ 42,634	$ -	$ -	$ 42,634
GRA TBA-1 (3 yr)	$ 34,119	$ -	$ -	$ 34,119
Interns (3/3mo summer, 4 yr)	$ 29,700	$ -	$ -	$ 29,700
Supplies and Equipment	$ 61,451	$ -	$ -	$ 61,451
Contractual WRWA	$ 13,750	$ -	$ -	$ 13,750
TOTAL INDIRECT @ 55%	$ 259,412	$ -	$ -	$ 259,412
Total Budget	$ 884,717	$ -	$ 88,472	$ 973,189
Total Match				$ 88,472
TOTAL REQUEST	$ 884,717			

Budget Narrative

Project Task **EPA Task Budget** [1]

Task 1: Oyster Deployments in Cockeast Pond **$397,858**

Approximately 1 million oyster seed will be deployed either as singles or remote set as appropriate factoring 50% survivability in years 2 and 3. Method of deployment and required gear will depend on site assessment based on year 1 test deployment of 20,000 seed. Deployment will include surface bags, bottom racks and bottom plots. Students and interns will be utilized to tend to the oyster deployments with supervision by scientific staff of CSP and WRWA scientists. Field support will also be provided by the Town of Westport Shellfish Department.

Task 2: Sampling for Cockest Pond Oyster Deployment (Water Quality) **$42,000**

Sampling stations will be established inside and outside the oyster aquaculture area in a pattern to assess near and far field effects and will build on previous sampling locations in order to relate new water quality data to historical data collected by WRWA in collaboration with CSP. An upward looking ADCP will be placed in the deployment area to determine the direction of water transport in the 24 hrs prior to the sampling. Sampling will be undertaken bi-weekly during each of the 4 summer growing seasons (May-September) with an additional sampling taking place in April before the growing season and again in October/November after the growing season. Approximately 10-12 sampling events will be undertaken in a given year. During each sampling event a sample of pond outflow will be collected and paired to velocity measurements.

Task 3: Time-series Dissolved Oxygen (DO)/Chl-a Moorings **$86,282**

YSI-6600 moorings (6) will be deployed to measure dissolved oxygen, salinity, temperature and chlorophyll-a (via fluorescence) both inside and surrounding the area potentially affected by the deployment of oysters. HOBO light sensors will deployed in association with the moorings to quantify light attenuation (as an indicator of turbidity). The moorings will be maintained from Jul. 1 – Sept. 30 within the portion of the Cockeast Pond system where oyster aquaculture is being monitored and moorings will calibrated bi-weekly over each season.

Task 4: Bio-deposition Rates and Bio-deposit Impact Areas **$84,590**

CSP scientists will quantify particulate capture and deposition from oysters within oyster aquaculture areas using particle traps attached to the oyster bags or separate cages over a range of particulate concentrations. Data collected from particle traps will be used to track PON deposited by oysters and determine individual oyster bio-deposits and 24 hour bio-deposition rates of carbon and nitrogen. The sediment surface influenced by the oyster deposition will be quantified using acoustic velocity measurement techniques refined by CSP scientists in other oyster aquaculture studies conducted on Cape Cod. The relationship of water column particulate levels and biodeposition rate will be determined over the range of oyster sizes, time and

deployment approaches. This is also important for defining the sediment areas receiving biodeposits to guide the SOD, nitrogen dynamics and denitrification measurements.

Task 5: Sediment Core Incubations and Analysis of Denitrification and Particulate Organic Nitrogen (PON) Cycle $150,237

Sediment cores (12 to 16) will be collected by diver on an annual basis during the late summer field season and incubated in a field laboratory in order to quantify sediment oxygen uptake (carbon turnover) and nutrient fluxes both within the oyster aquaculture area and outside of the area potentially influenced by the oysters. Most critically, CSP scientists will directly measure denitrification rates to quantify the degree to which intensive oyster aquaculture can change sediment nutrient flux rates through enhancement of denitrification. Denitrification is routinely measured in estuarine and fresh pond sediments by High Precision Membrane Inlet Mass Spectrometry, where N_2 excess is measured using membrane-inlet mass spectrometry (MIMS) in the SMAST Stable Isotope Facility (M. Altabet). N2 produced by denitrification against the large background of atmospheric N2 is precisely detected by analysis of its ratio with the inert gas Argon.

Task 6: Reporting and Community Engagement $123,750

Annual progress will be documented in the form of a Technical Memorandum summarizing work completed in a given year. The results will be presented in at an annual workshop at UMD's conference facility (ATMC) previously used for MEP municipal outreach efforts. The target audience will be municipalities engaging in restoration of shellfish areas for nitrogen management. Presentations at a national scientific meeting and a estuarine restoration meeting will also be made. Summary of results will be presented through the WRWA newsletters, local and regional press and public access television. The UMD Communications Specialist (A. Wartts) will develop weekly and/or monthly releases for this project, as appropriate, and a web presence for the project's progress and results. Upon completion of the project a full draft and final report will be developed summarizing findings as well as in scientific journals. Content from the Technical Memoranda and report will also be made available through the WRWA website as well as the CSP website and project blog. The report will be circulated to all the southeastern Massachusetts Towns that participated in the Massachusetts Estuaries Project and are now shifting into the implementation phase. Project staff will also include the results in the annual presentations to over 15 communities conducting water quality monitoring associated with CSP and to the regional planning agencies (Cape Cod County Commission, Martha's Vineyard Commission, SRPEDD and Nantucket) which support watershed management throughout s.e. Massachusetts.

Project Match (10%) $88,472

Matching funds for the effort are a combination of both in-kind and direct funds. Direct funding stems from the UMASS President's Science and Technology Seafood Collaborative Project on which Dr. Howes is a Co-PI (R. Hannigan P.I.). These funds will support initial graduate student support (year 1) for the nitrogen removal efficiency of various oyster deployment approaches ($16,072). In-kind support will be provided through UMD to cover some of Dr. Howes time (salary, fringe, IC) in each of the 4 years (0.5 mo/yr, $52,400 total) related to project oversight,

data analysis and presentations to the public, municipalities and associated agencies. Similarly, the Westport River Watershed Alliance will provide $5,000/year support for Lizabeth White, to work on the science/advocacy portion of the project ($20,000 total).

TOTAL PROJECT BUDGET		**$973,189**
	USEPA (this proposal) =	**$884,717**
	Matching funds =	**$88,472**

[1] **Task breakdown is for USEPA requested funds only.**

Letters of Support

1) Westport River Watershed Alliance
2) Town of Westport Board of Selectmen
3) Town of Westport Shellfish Department

WESTPORT RIVER WATERSHED ALLIANCE

To restore, protect, celebrate and sustain the natural resources of the Westport River and its watershed

Dr. Brian Howes
Director, Coastal Systems Program
Department of Estuarine and Ocean Science
School for Marine Science and Technology
University of Massachusetts-Dartmouth
706 South Rodney French Blvd, Lab 116
New Bedford, MA. 02744-1221

April 6, 2016

Dear Dr. Howes:

The Westport River Watershed Alliance (WRWA) is pleased to partner with the Coastal Systems Program (CSP) at the School for Marine Science and Technology-UMass Dartmouth (SMAST) on a collaborative proposal to the Southeast New England Program for Coastal Watershed Restoration. This proposal focuses on the use of shellfish to assist in the remediation of nutrient-enriched waters, which is critical for the Westport River, as it is on the EPA's 303(d) List of Impaired Waters for nitrogen.

The Westport River Watershed Alliance (WRWA) is a nonprofit environmental and advocacy group formed in 1976 with a mission to preserve and protect the natural resources of the Westport River and its watershed. We are committed to upholding this mission and believe that this proposal offers a significant opportunity to make an impact on reducing nitrogen pollution.

Shellfish aquaculture is becoming recognized as an innovative and cost-effective means of nitrogen remediation, and this project proposes to use it as a transferrable and sustainable method of restoration in the Westport River Estuary. The proposal addresses a variety of needs and issues in the Westport River watershed, such as nitrogen mitigation, water quality management, and the re-establishment of historic oyster beds. It integrates habitat and water quality in priority sites in the River, and will provide measurable and significant environmental results which will benefit not only the Westport River itself but also the economic and social fabric of the entire watershed, with results transferable to other communities considering shellfish aquaculture to serve similar purposes.

This project will be a collaboration between a diverse group of stakeholders, which will include SMAST, WRWA, The Town of Westport through their Shellfish Warden and Fish Commissioners, the MA Division of Marine Fisheries, and the fishing community, as well as local residents and beach clubs.

P.O. Box 3427 • 1151 Main Road • Westport, Massachusetts 02790-0703
Tel (508) 636-3016 • Fax (508) 636-8884 • info@wrwa.com • www.westportwatershed.org

WRWA's role in this project will be multi-faceted and will focus on both science and outreach. We have had a sampling program for Cockeast Pond for many years and will continue to perform all water quality sampling in coordination with the CSP. We will also be involved in the set-up of the various oyster gear as well as the deployment of the oysters. Additionally, WRWA will engage in community outreach by distributing information to residents regarding the project and its results on our website and Facebook page. We will work closely with the CSP to include videos, data, and other relevant information gathered for the project. We will also assist in arranging and participate in local workshops and presentations.

The WRWA looks forward to working with the Coastal Systems Program and others on this project, and we hope that it results in successful outcomes and leads to other collaborative endeavors in the future.

Sincerely,

Deborah Weaver

Deborah Weaver
Executive Director
Westport River Watershed Alliance
1151 Main Road
Westport, MA. 02790
(508)636-0290
www.westportwatershed.org

TOWN OF WESTPORT

816 Main Road
Massachusetts 02790
The Coastal Agricultural Resource Community of New England
BOARD OF SELECTMEN

Tel. (508) 636-1003
Town Administrator (508) 636-1150
Fax. (508) 636-1147

March 29, 2016

Dr. Brian Howes
Director, Coastal Systems Program
Department of Estuarine and Ocean Science
School for Marine Science and Technology
University of Massachusetts-Dartmouth
706 South Rodney French Blvd, Lab 116
New Bedford, MA. 02744-1221

Dear Dr. Howes:

The Town of Westport is pleased to partner with the Westport River Watershed Alliance (WRWA) and the Coastal Systems Program (CSP) at the School for Marine Science and Technology-UMass Dartmouth (SMAST) on the grant proposal to the Southeast New England Program for Coastal Watershed Restoration. This proposal, which is focused on aquaculture, presents opportunities for the Town to address the nutrient enrichment of the Westport River by implementing "soft" solutions as described in the grant. The Westport River is a 303d listed waterbody impaired for nitrogen, and the Town recently received a draft of the TMDL for the River.

The Town of Westport has a long history of shellfishing and is committed to preserving and protecting its natural resources. Westport has been working diligently to address sources of pollution to the Westport River and to find solutions that will help improve the River's water quality and overall health. Projects such as this, which are a collaboration of stakeholders and which utilizes the resources of these stakeholders, are becoming the most cost-effective, environmentally successful methods of addressing nutrient pollution in waterbodies. In addition, they provide information that can be used throughout the watershed and the region.
We are looking forward to working with our partners on this project and hearing about the findings of this study.

Respectfully,

Craig J. Dutra
Chairman
Westport Board of Selectmen

TOWN OF WESTPORT
2061 Main Road, Westport, MA 02790
Christopher A. Leonard
Office of the Shellfish Constable/Wharfinger
Tel: 508-636-1105 or Fax 508-636-1147

March 25, 2016

Dr. Brian Howes
Director, Coastal Systems Program
Department of Estuarine and Ocean Science
School for Marine Science and Technology
University of Massachusetts-Dartmouth
706 South Rodney French Blvd, Lab 116
New Bedford, MA. 02744-1221

Dear Dr. Howes:

The Town of Westport Shellfish Department is pleased to partner with the Coastal Systems Program (CSP) at the School for Marine Science and Technology-UMass Dartmouth (SMAST) on a collaborative proposal to the Southeast New England Program for Coastal Watershed Restoration. This proposal, which focuses on the use of shellfish to assist in the remediation of nutrient-enriched waters, will provide valuable information to the Town as it moves forward with restoration of its coastal resources. More importantly, this work will help other Towns across the southeastern Massachusetts region by providing quantitative guidance on the efficacy of shellfish as a water quality management strategy.

Shellfish aquaculture is becoming recognized as an innovative and cost-effective means of nitrogen remediation, however, there is a critical need for proper assessment of the suitability of impaired systems to support shellfish aquaculture. Additionally, scientific documentation of the benefit that shellfish aquaculture can have in improving an impaired habitat and guidance on how to integrate the approach into the regulatory (TMDL) framework is paramount to successfully advancing this biological approach to restoration. If funded, this proposal will provide measurable and significant environmental results which will benefit not only the Cockeast Pond / Westport River system specifically but also will help sustain the economic and social fabric of the entire watershed, with results transferable to other communities considering shellfish aquaculture to the same end.

This project will be a collaboration between a diverse group of stakeholders, of which the Town of Westport Shellfish Department is but one. The Shellfish Department is pleased to provide its local knowledge of shellfishing habitat in the Westport River and Cockeast Pond systems in addition to providing field and logistical support during the execution of the project. As it may be needed, the Town of Westport Shellfish Department is also willing to provide boat support to facilitate the science to be undertaken through the grant.

Sincerely,

Chris Leonard - Shellfish Warden
Town of Westport, MA.

Curriculum Vitae

Dr. Brian L. Howes - Professor / Director, Coastal Systems Program

Dr. Roland Samimy - Senior Research Manager, Coastal Systems Program

Dr. David Schlezinger - Senior Research Manager, Coastal Systems Program

BRIAN L. HOWES, PH.D.
Professor, School of Marine Science and Technology
Director, Coastal Systems Program
University of Massachusetts, Dartmouth
New Bedford, MA 02744
(508) 910-6314; bhowes@umassd.edu

EDUCATION:

B.A., 1974, Rutgers College of Arts & Sciences, Rutgers University
---- 1974-1975, Special Student, Rutgers College of Arts & Sciences
---- 1980, Guest Lecturer, Institute of Ecology & Genetics, Univ. Aarhus, Denmark
M.A., 1980, Boston University Marine Program
Ph.D., 1984, Boston University Marine Program
---- 1984-85, Postdoctoral Investigator, Woods Hole Oceanographic Institution

POSITIONS HELD:

Current:

Professor, School of Marine Science and Technology, U.Mass. Dartmouth, 2001-
Director, Coastal Systems Program (for restoration of coastal bays & wetlands), 1997-
Technical Director, Massachusetts Estuaries Project, 2002-
Faculty, Univ. of Mass. Intercampus Graduate School of Marine Sciences 2000-

Past:

Visiting Investigator, Woods Hole Oceanographic Institution, 1986-1987
Visiting Assistant Research Prof. Ctr. Coastal Environ. Studies, Rutgers Univ., 1987-1988.
Graduate Faculty Associate Member, Rutgers Univ. Ecology Prgm., 1988-1997
Assistant Scientist, Woods Hole Oceanographic Institution, 1987-1991
Associate Scientist, Woods Hole Oceanographic Institution, 1991-1997
Hydrologist, U.S.G.S. Water Resources Division on IPA, 1987-98
Guest Investigator, Woods Hole Oceanographic Institution, 1997-2000.
Adjunct Professor, Boston University Department of Earth Sciences, 1989- 2003
Adjunct Professor, Boston University Marine Program, 1995-2003
Senior Fellow, Center of Marine Science and Technology, U.Mass. Dartmouth, 1997-2001.
Adjunct Professor, Dept. Wildlife & Conservation, U.Mass. Amherst, 1998-2003

SELECTED PUBLICATIONS:

Dr. Howes has published 78 scientific articles, 11 general articles and over 100 technical publications on coastal processes. Selected relevant publications are presented below:

2000 McKnight, D.M., B.L. Howes, C.D. Taylor, D.D. Goehringer. Phytoplankton dynamics in a stablely stratified Antarctic lake during winter darkness. Journal of Phycology 36:852-861.

2000 Bazylinski, D.A., D.R. Schlezinger, B.L. Howes and R.B. Frankel. Occurrence and distribution of diverse populations of magnetic protists in a chemically-stratified coastal salt pond. Chemical Geology. 169:319-328.

2002* Hamersley, M.R. and B.L. Howes. Control of denitrification in a septage-treating artificial wetland: The dual role of particulate organic carbon. Water Research 36:4415-4427.

2003 Rengefors, K., K.C. Ruttenberg, C.L. Haupert, C. D. Taylor, B.L. Howes and D.M. Anderson. Experimental investigation of taxon-specific response of alkaline phosphatase activity in natural freshwater phytoplankton. Limnology and Oceanography 48:1167-1175.

2003* Hamersley, M.R. and B.L. Howes. Contribution of denitrification to nitrogen, carbon and oxygen cycling in tidal creek sediments of a New England salt marsh. Marine Ecology Progress Series 262:55-69.

2004* Hamersley, M.R., B.L. Howes, and D.S. White. Particulates, Not Plants, Dominate Nitrogen Processing in a Septage-Treating Aerated Pond System. Journal of Environmental Quality 32:1895-1904.

2005* Hamersley, M.R. and B.L. Howes. Coupled nitrification-denitrification measured in situ in a Spartina alternaiflora marsh with a 15NH4 tracer. Mar. Ecology Prog. Series 299:123-135.

2005 Howes, B.L., J.M. Teal and S. Peterson. Experimental Phragmites control through enhanced sediment sulfur cycling. Ecological Applications 25:292-303.

2007 Smith, M.P, B.L. Howes and J. Kimball. Chapter 9, Watershed Planning: Securing our water future. In: Water: Managing a Finite Resource. E.M. Hamin, L. Silka and P. Geigis. University of Massachusetts Press. pp. 121-133.

2007 Ramsey, J.S., H.E. Ruthven, S.W. Kelley and B.L. Howes, 2007. Quantifying the influence of inlet migration on tidal marsh system health. ICCE Proceedings of International Conference of Coastal Engineering, Vol.2, pp. 2082-2094.

2013 Medeiros, D. L., D.S. White, B.L. Howes. Replacement of Phragmites australis by Spartina alterniflora: The Role of Competition and Salinity. *Wetlands, Journal of the Society of Wetland Scientists*, DOI 10.1007/s13157-013-0400-6

2013 Benson J.L., D.R. Schlezinger, B.L. Howes. Relationship between nitrogen, light, and Zoster marina habitat quality and survival in southeastern Massachusetts estuaries. Journal of Environmental Management. 2013 Dec 15; 131-129-37. doi: 10.1016/jenvman.2013.09.033. Epub 2013 Oct 23.

2014 Sawabini, A.M., D.R. Schlezinger, M.A. Sundermeyer, B.L. Howes. Regional Forcing by Light on Dissolved Oxygen Levels in Shallow Temperate Estuaries. Estuaries. . (in press).

2014 Tucker, J. A.E. Giblin, C.S. Hopkinson, S.W. Kelsey, B.L. Howes. Long-term response of benthic metabolism and nutrient cycling to reductions in wastewater loading to Boston Harbor, USA. Estuarine, Coastal and Shelf Science. (in Press).

2015 Howes, B.L., Samimy, R.I. The Massachusetts Estuaries Project: University Engagement of Municipalities and Citizens, State and Federal Regulatory Agencies and NGOs, to Rehabilitate and Sustain the Environmental Resources of Coastal Massachusetts. Compilation of UMD Community Engagement. In Press.

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School for Marine Science and Technology
University of Massachusetts-Dartmouth
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Education and Training

Ph.D.	**University of Massachusetts-Dartmouth, SMAST** Discipline: Coastal Systems Science Date Conferred: May 2013
M.S.	**Tufts University**, Medford, MA Discipline: Water Resources Engineering Conferred: May 1994
M.A.	**Tufts University**, Medford, MA Discipline: Environmental Policy Conferred: May 1994
B.A.	**Tufts University**, Medford, MA Major: English Conferred: May 1990

Professional Experience

University of Massachusetts-Dartmouth, SMAST **March 2002-Present**
Senior Research Manager, Coastal Systems Program
Department of Estuarine and Ocean Science
Dr. Samimy has been working primarily on the Massachusetts Estuaries Project as the Projects Technical Coordinator and Technical Lead in Hydrology. Dr. Samimy's Technical tasks include but are not limited to: (a) conducting a regional stream gauging and constituent transport assessment, (b) freshwater pond nutrient related assessments, (c) estuarine data collection on water quality, biogeochemical processes, and moored instrumentation program, and (d) data analysis, assessment and technical report preparation. .

Camp, Dresser and McKee Inc. **January 1995-February 2002**
Water Resources Scientist
Responsible for a variety of water resources projects related to water supply studies, nutrient dynamics in aquatic systems, coastal water quality monitoring related to wastewater effluent discharges, groundwater and surface water hydrology, contamination assessment and remedial action planning, and aquifer analyses. By example, Dr. Samimy was a member of a three person team performing the 1999 water supply assessment for the Republic of Palau through a CDM contract with the Office of Foreign Disaster Assistance (OFDA). Additionally, was part of a broader team of scientists and engineers involved in the design of a 40 mgd membrane water treatment plant for the City of Boca Raton, Florida. Specifically, Dr. Samimy was responsible for the operation, maintenance, and testing of the pilot membrane unit that served as the basis of the final design for the full-scale plant.

Select Publications

Howes, B.L., R.I.Samimy, (2005) Summary of Water Quality Monitoring Program for the Plymouth, Kingston and Duxbury Harbor Embayment System (2003 –2004), 86 pp. Final Report to the South Coastal Basin Estuaries Monitoring 604(b) Program.

Howes, B.L, **R.I. Samimy**, S. Kelley (2007). Summary of Results of November 2007 Eastport, Maine Hydrodynamic Survey. Technical Memorandum submitted to Ocean Renewable Power Corporation.

Howes, B.L, **R.I. Samimy**, S. Kelley (2007). Summary of Results of September 2007 Eastport, Maine Hydrodynamic Survey. Technical Memorandum submitted to Ocean Renewable Power Corporation.

Howes B., **R.I. Samimy**, T. Ruthven, E.M. Eichner, J. S. Ramsey, D. Schlezinger (2013). Massachusetts Estuaries Project Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Salt Pond Embayment System, Town of Falmouth, MA, Massachusetts Department of Environmental Protection. Boston, MA.

Howes B., S. Kelley, J. S. Ramsey, E. Eichner, **R. I. Samimy**, D. Schlezinger, P. Detjens (2013). Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Scorton Creek Estuarine System, Town of Sandwich, Massachusetts, Massachusetts Department of Environmental Protection. Boston, MA.

Howes B., S. Kelley, J. S. Ramsey, E. Eichner, **R. I. Samimy**, D. Schlezinger, P. Detjens (2013). Massachusetts Estuaries Project Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Sandwich Harbor Estuarine System, Town of Sandwich, Massachusetts, Massachusetts Department of Environmental Protection. Boston, MA.

Howes B.L., **R.I. Samimy**, E.M. Eichner, S.W. Kelley, J.S. Ramsey, D.R. Schlezinger (2013). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Wareham River, Broad Marsh and Mark's Cove Embayment System, Wareham, Massachusetts, SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

Howes B.L., S.W. Kelley, **R.I. Samimy**, E.M. Eichner D.R. Schlezinger, J. S. Ramsey (2014). Linked Watershed-Embayment Model to Determine the Critical Nitrogen Loading Threshold for the Lake Tashmoo Estuary, Towns of Tisbury, West Tisbury and Oak Bluffs, MA. SMAST/DEP Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

Howes B.L., D.R. Schlezinger, **R.I. Samimy,** (2014). Shellfish Aquaculture Demonstration Project Little Pond Monitoring 2013-2014 Oyster Deployment, Town of Falmouth, MA.

Howes B.L. and **R.I. Samimy**, (2014). Summary of Stream Flow and Water Quality Monitoring Activities in Bread and Cheese Brook (MEP watershed #3) October 2012-October 2014. Town of Westport, MA.

Howes, B.L., **Samimy, R.I.**, (2015). The Massachusetts Estuaries Project: University Engagement of Municipalities and Citizens, State and Federal Regulatory Agencies and NGOs, to Rehabilitate and Sustain the Environmental Resources of Coastal Massachusetts. Compilation of UMD

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Education:
Boston University, Boston, MA; Ph. D. Marine Geology, January 2002
Amherst College, Amherst, MA; B.S. Biology, May 1988

Awards:
Shaklee Antarctic Research Fellowship, Sept. 1995-Dec. 1995
Teaching Fellowship, Boston University Marine Program, Sept. 1992-Dec. 1992
Teaching Fellowship, Boston University Earth Sciences Department, Sept. 1989-May 1989
Research Experience for Undergraduates, May 1989-Aug. 1989

Positions Held:
University of Massachusetts, Dartmouth School of Marine Science and Technology, New Bedford, MA.
July 2001-Present Senior Research Manager, Coastal Systems Program
University of Massachusetts, Dartmouth School of Marine Science and Technology, New Bedford, MA.
May 1997-July 2001 Guest Student
Woods Hole Oceanographic Institution; Woods Hole, MA
Sept. 1989-May 1997 Guest Student
Sept. 1988-May 1989 Research Assistant
National Sea Grant College Program; Silver Springs, MD
June 1987-May 1988 Communications Assistant (writer/editor)

Consultant To (at various times):

National Park Service	Louis Berger International
Camp Dresser McKee	Woods Hole Group

Professional Activities:
Reviewer for National Science Foundation, Division of Polar Programs; 1995
Reviewer for Estuaries; 1993

Publications:
Bazylinski, D. A., Schlezinger, D. R., Howes, B. H., Frankel, R. B., Epstein, S. S. 2000. Occurrence and distribution of diverse populations of magnetic protists in a chemically stratified coastal salt pond. Chemical Geology. 169: 319-328.

Schlezinger, D. R. and B. L. Howes. 2000. Organic phosphorus and elemental ratios as indicators of prehistoric human occupation. Journal of Archaeological Science 27: 479-492.

Howes, B.L. and D.R. Schlezinger. 1998. Nutrient Related Water Quality within the Popponesset Bay System. Environment Cape Cod . 2(1): 1-21.

Howes, B. L., D. R. Schlezinger, D. D. Goehringer, and S. Brown-Leger. 1992. Carbon cycling in a redox stratified antarctic lake, Lake Fryxell. U. S. Antarctic Journal 27(5): 263-265.